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High-voltage capacitor charging made simple

By Bruce Haug

DESIGNING A HIGH-VOLTAGE capacitor charger or power supply up to a thousand volts is not a trivial task. A discrete solution uses a general-purpose flyback PWM (pulse-width modulation) controller with an optocoupler, monitoring, status and protection features. This solution normally requires lots of circuitry and is of high design complexity.

It is essential to avoid an input over-current fold-back condition that can occur during turn-on due to the capacitive load looking like a short circuit. Care must also be taken to make sure that this type of converter turns on only when the input voltage is within the safe operating range to ensure its long-term reliability. It is also convenient to determine when the high-voltage output capacitor is fully charged without a physical sense connection to its high voltage, which eliminates the need for another part crossing the isolation barrier. Depending on the application, the user might also want to have the ability to select a suitable gate-drive voltage.

The need for developing a high voltage across a capacitor can be required for professional high-voltage photoflash systems, security-control systems, pulsed radar, automotive air-bags, emergency strobes, security/inventory control systems and detonators. Reliability, cost, safety, size and performance are the major design obstacles that a high-voltage power supply designer must contend with.

However, the recently introduced LT3751 from Linear Technology greatly simplifies this design task. The LT3751 is full-featured flyback controller designed to rapidly charge large capacitors to voltages as high as 1,000 V. It is an improved, second-generation version of the previously released LT3750, with additional features that include the ability to sense the output voltage from the primary or secondary side of the transformer, accept a higher input voltage, along with having more programmability and protection features. The LT3751 drives an external N-Channel MOSFET and can charge a 1,000 µF capacitor to 500 V in less than 1 second. Furthermore, it can be configured for primary-side output-voltage sensing without the need for an optocoupler.

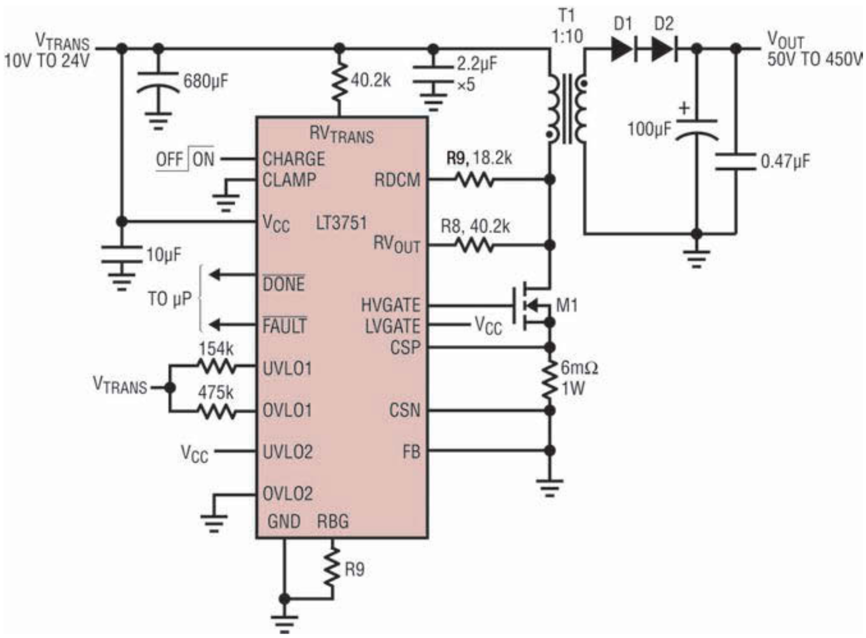

Figure 1: LT3751 applications circuit with primary-side output-voltage sense

For lower noise and tighter output-regulation applications, a resistor-divider network from the output voltage can be used to regulate the output, making it well suited for high-voltage power-supply requirements. The transformer's turns ratio and two external resistors easily program the output voltage. In addition, the LT3751 has an internal 60-V shunt regulator that is powered through a series resistor and can operate from input voltages ranging from 4.75 V up to 400 V. This enables the end-user to accommodate an extremely wide range of input-power sources, unavailable in a single package until now. Its V_{CC} input accepts voltages ranging from 5 V to 24 V. The LT3751 operates in boundary mode, which is between continuous-conduction mode (CCM) and discontinuous-conduction mode (DCM). Boundary-mode control

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minimizes transition losses, reduces transformer size and configures the part to easily ramp up without going into current limit when powering a capacitive load. Another advantage of boundary mode is that it reduces large-signal stability issues that can arise from using a voltage mode or PWM technique and can deliver up to 88% efficiency, along with providing a fast transient response. Output-voltage regulation is achieved by dual overlapping modulation, using both peak primary-current modulation and duty-cycle modulation.

The circuit in **Figure 1** shows the LT3751 operating with the output voltage being sensed via the primary-side winding of the transformer. This method of primary-side output-voltage sensing maintains isolation with only one part, namely the power transformer crossing the isolation barrier, and is a very simple circuit. The output voltage is sensed through the RV_{OUT} pin and is programmed by the selection of R8, R9 and the transformer-turns ratio. This isolated circuit charges a capacitor to 450 V from a 12 V to 24 V input, using the on-board differential DCM comparator. The transformer (T1), part number 75031040, is available off-the-shelf from Wurth Electronics.

The differential operation of the DCM comparator allows the LT3751 to accurately operate from high-voltage inputs of up to 400 V or even higher. Furthermore, the V_{OUT} comparator and DCM comparator are needed for lower input voltages down to 4.75 V, with the use of a logic-level external MOSFET. This permits the user to accommodate an extremely wide range of power sources. Only five external resistors are needed to operate the LT3751 as a capacitor charger. The output voltage trip point (V_{OUT}) can be adjusted from 50 V to 450 V by using this equation:

$$R_9 = \left(\frac{0.98 \times N}{V_{OUT} + V_{DIODES}} \right) \times R_8$$

where *N* is the turns ratio of the transformer and V_{DIODES} is the voltage drop across D1 and D2.

The LT3751 stops charging the output capacitor once the programmed output-voltage trip point is reached. The charge cycle is repeated by toggling the CHARGE pin. The maximum charge/discharge rate in the output capacitor is limited by the temperature rise in the transformer and power dissipation in the external MOSFET. Limiting the transformer surface temperature in Figure 1 (using the Wurth off-the-shelf transformer part number 75031049) to 40°C rise above ambient with no air flow requires the average output power to be less than or equal to 40 W.

The maximum available output power can be increased by making the transformer larger and providing forced-air cooling. ■

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